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GGS ULTRAVIOLET IMAGER

KEY PARAMETER GENERATION SOFTWARE

DESIGN DOCUMENT

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Abstract

This document presents background and design information on the Key Parameter Generation Software (KPGS) for the Ultraviolet Imager (UVI) instrument on the POLAR spacecraft. Discussion includes program design, input/output data formats, and resource requirements. Also included are complete instructions for compiling and linking the source code to produce a working executable, detailed test instructions, and anticipated results.

Contents

1 INTRODUCTION

1.1 Purpose

The purpose of this document is to provide background and design information on the key parameter generation software (KPGS) for the POLAR UVI instrument and to provide information on the building and testing of the KPGS in both the UVI Remote Data Analysis Facility (RDAF) and the CDHF development environments.

1.2 Applicable Documents

The following documents form a part of this document to the extent specified herein.

Reference 1 ISTP CDHF Software System Programmer's Guide to Key Parameter Generation Software, Revision 4 (CSC/SD-92/6028; 560-7SUG/0290), May 1995.

Reference 2 Data Format Control Document Between the ISTP Program Information Processing Division Ground Data Processing System and the ISTP Mission Investigators, (CSC/TR-91/6014; 560-1DFD/0190), November 1993.

Reference 3 ISTP CDHF Key Parameter Generation Software Integration Test Plan, (CSC/TM-91/6084), July 1992.

Reference 4 ISTP Key Parameter Generation Software Standards & Conventions, Version 1.3, March 1994.

Electronic versions of a User's Guide and a Programmer's Guide are also part of the UVI KPGS documentation set and will be included with the software delivery. A Postscript version of this document will also be included with the software delivery.

1.3 Investigation Objectives

The primary objective of this investigation is to obtain global images of the aurora in carefully selected spectral regions in the far ultraviolet (FUV). The auroral images are composed of an array of simultaneously acquired pixel elements. This method of acquisition allows temporally coherent information to be obtained across each of the images. From these images the following information may be obtained by scientific analysis: location, extent, and spatial characteristics of the auroral phenomena (representing the mapping of particle precipitation down into the atmosphere via the intermediate acceleration regions); total energy deposition rate; characteristic energy of the precipitation particles; and activity indices. Images of the limb of the auroral emissions will also be obtained and will provide altitude distribution information normally lacking in the column integrated images.

1.4 Basic Measurement Parameters

The basic measurement parameters are two-dimensional images in the various spectral bandpasses. The imager has a circular field of view which is mapped onto a rectangular pixel array. Only the circular array of pixels corresponding to the mapped field of view (active pixels) are of interest. The remaining pixels comprising the corners of the rectangular image contain no information. There are 36,728 active pixels, each of which is digitized to 12 bits. Because of the large amount of digital information comprising each image and the limited telemetry bandwidth available to UVI, each image is spread over multiple major frames, typically 4. Only the active pixels are transmitted and instrument housekeeping information is included in the UVI science data.

On the ground, the major frames are combined to form a single auroral image. Since only the (circular) active pixel image is transmitted from UVI, each auroral image is filled to create a rectangular image composed of 228 x 200 spatial elements. UVI housekeeping data is also extracted to enable proper sequencing of the KPGS algorithm.

2 PROGRAM DESIGN

2.1 Major Functions

The major functions of the UVI KPGS are:

a) reconstruct auroral image data from the UVI level-0 data,
b) subtract background from the selected image,
c) convert reconstructed images into spectrally corrected images (in radiance units),
d) calculate pointing information for the selected image, and
e) output key parameters in standard format.

2.2 Inputs and Outputs

The inputs to the UVI KPGS are listed below.

Type	Size
UVI level-0 data file	153 MBytes/day (Ref. 2)
UVI calibration data files (5 files)	2.9 MBytes each
UVI parameter data file	720 Bytes/day
POLAR spacecraft orbit data file	87 kBytes/day *
POLAR spacecraft attitude data file	32 kBytes/day *

POLAR spacecraft housekeeping data file	24 Mbytes/day * *as used in delivery tests

The UVI level-0 data file contains the raw image data as well as embedded UVI housekeeping data which is used by the UVI KPGS to make sequencing and error handling decisions. The UVI calibration data file is used to provide detector calibration as a function of instrument gain, detector, and filter. The UVI parameter data file sets the UVI KPGS operating modes and can be used to control the amount and detail of data output and debug information. The POLAR spacecraft orbit and attitude data files are used to provide spatial registration of the images by allowing the calculation of latitude and longitude coordinates for each pixel of the image. To complete this task, the UVI KPGS must also know the despun platform offset angle from nadir which is contained in the POLAR spacecraft housekeeping data file.

The outputs from the UVI KPGS are listed below.

Type	Size
UVI key parameter file	36.4 MBytes/day
user message log file	< 850 kBytes/day
suggested color table	TBD
UVI scratch file	184 kBytes/day

The UVI key parameter data file is a CDF file with the format specified in Appendix A. The key parameter file contains one set of key parameters for approximately every 10 minutes and spans 24 hours. All messages from the UVI KPGS will be written to a single user message log file. If the KPGS is operated in one of its diagnostic modes, corresponding diagnostic messages will also be written to the user message log file. The size of the log file is a function of the amount of data processed, the frequency of writing key parameter records, and the level of debug information requested. The UVI scratch file is used to store a copy of the most recent background image for use if no new background can be found.

2.2.1 Key Parameter Characteristics

UVI key parameters consist of image data and additional data related to the images. The characteristics of both types are listed in Table 2.2.1. The complete format is specified by the skeleton table in Appendix A. Delvery tests with a nominal output period of 5 minutes produced 195 output records.

Table 2.2.1 Key Parameter Characteristics

Parameter	Name	Type	Values/ KPF record
1. Absolute time code	EPOCH	CDF_EPOCH	1
2. Absolute time code	Time_PB5	CDF_INT4	3
3. Relative time code	IMG_MINUS_MSEC	CDF_REAL8	1
4. Relative time code	IMG_PLUS_MSEC	CDF_REAL8	1
5. Indicator of gaps in processed data	POST_GAP_FLAG	CDF_INT4	1
6. Indicator of quality of key parameters	QUALITY_FLAG	CDF_INT4	1
7. Expected record spacing	NOMINAL_OUTPUT _PERIOD	CDF_INT4	1
8. Detector label	SYSTEM	CDF_INT4	1
9. Observing sequence	SEQ	CDF_INT4	1
10. Instrument operating mode	MODE	CDF_INT4	1
11. Instrument gain setting	GAIN	CDF_INT4	1
12. Aperture door position	DOOR	CDF_INT4	1
13. Spacecraft position vector	GCI_POSITION	CDF_REAL4	3
14. Spacecraft attitude vector	ATTITUDE	CDF_REAL4	3
15. Sun position vector	GCI_SUN	CDF_REAL4	3

Table 2.2.1 Key Parameter Characteristics continued

Parameter	Name	Type	Values/ KPF record
16. Look direction for center of field of view	GCI_LOOK_DIR	CDF_REAL8	3
17. Despun platform nadir offset angle	DSP_ANGLE	CDF_REAL4	1
18. Image label	FILTER	CDF_INT4	1
19. Selected auroral image	IMAGE_DATA	CDF_REAL4	4.6E4
20 & 21. Pointing information for the auroral image	GEODETIC_LAT GEODETIC_LONG	CDF_REAL4 CDF_REAL4	460 460

2.2.2 UVI Key Parameter Descriptions

1,2. (EPOCH, Time_PB5) These are as required by Reference 1. They refer to the time corresponding to the center of the image contained in IMAGE_DATA.

3,4. (IMG_MINUS_MSEC, IMG_PLUS_MSEC) These specify the beginning and end time of the image contained in IMAGE_DATA. The time is specified as an offset in milliseconds from the center time given by EPOCH and Time_PB5.

5. (POST_GAP_FLAG; range: 0 to 15) This is as specified in Reference 4. A gap is defined as being greater than twice the nominal output period given in NOMINAL_OUTPUT_PERIOD. Values are specified for the following conditions. Note that this flags gaps preceding the current record. For information about gaps in the current record, inspect QUALITY_FLAG.

0	no gap
1	wrong mode
2	missing data
3	noisy data
10	high voltage turned off
11	first minor frame zero filled

12	internal telemetry sync not found
13	no background image found
14	desired image not found
15	image time outside desired time window
16	unknown causes.

6. (QUALITY_FLAG; range: ‘0000 0000’X to ‘7FFF FFFF’X) This is an INTEGER*4 variable with each bit (except the most significant bit) corresponding to a single flagged condition. Thus 31 separate quality conditions may be flagged simultaneously. The flagged conditions are arranged in order of severity. Hence the user may use masks to search for specific conditions or use a threshold to flag all conditions above a given level of severity. A quality condition is flagged by setting the corresponding bit to 1. The error free value for the flag is thus 0. Values for the quality flag are as follows.

QF_SFDU_ERROR	‘0000 0001’X error writing SFDU comment	‘0001’B
QF_TIME_OUT_OF_BOUNDS	‘0000 0002’X LZ0 data set outside of requested time	‘0010’B
QF_MINOR_FILL	‘0000 0004’X one or more minor frames with zero fill	‘0100’B
QF_MINOR_SYNC	‘0000 0008’X one or more minor frames with sync error	‘1000’B
QF_UNK_INTEGRATION	‘0000 0010’X unable to determine image integration time	‘0001 0000’B
QF_DSP_MOTION	‘0000 0020’X despun platform not stable	‘0010 0000’B
QF_POINTING	‘0000 0040’X the pointing calculations are not reliable	‘0100 0000’B
QF_BAD_TIME	‘0000 0080’X error in time calculation	‘1000 0000’B
QF_BAD_STAR	‘0000 0100’X error decoding star data	‘0001 0000 0000’B
QF_LZ_GAP	‘0000 0200’X gap in level zero data (≥ 1 major frame)	‘0010 0000 0000’B
QF_CALIBRATION	‘0000 0400’X calibration is unreliable	‘0100 0000 0000’B

QF_MISSING_BKG_IMAGE	'0000 0800'X missing background image	'1000 0000 0000'B
QF_MISSING_KP_IMAGE	'0000 1000'X missing requested KPF image	'0001 0000 0000 0000'B

7. (NOMINAL_OUTPUT_PERIOD) This is the expected time in minutes between key parameter records. The actual output period is a function of the availability and quality of image data. A gap is defined as being greater than twice the nominal output period.

8. (SYSTEM; values ±1) The UVI has two independent imaging systems. This parameter is an integer flag with the following values: +1 = PRIMARY, -1 = SECONDARY.

9. (SEQ; range: 1 to 49) The UVI may have up to 49 different observing sequences defined at any given time. A viewing sequence is a combination of detector, filter, gain, and integration settings that may be repeated as often as necessary. This parameter is the current observing sequence and may have valid values between 1 and 49. Note that the observation sequence definitions may be changed during the mission.

10. (MODE; range: 1 to 3) This parameter identifies which of three operating modes are in use. Key parameters are currently only processed for normal mode data in 9.2 second science telemetry mode. Valid values are listed below.

1	Normal mode
2	Star mode
3	Idle mode

11. (GAIN; range: 0 to 16) This is the instrument gain setting (1-16) with 16 being the highest setting. A gain setting of zero means the instrument is effectively off, even though the high voltage power supply may be enabled. Key parameters are only processed for nonzero gain settings.

12. (DOOR; values ±1) This specifies the position of the aperature door. Since the door is fitted with a MgF_2 data may be taken with the door closed. This parameter is an integer flag with the following values: +1 = OPEN, -1 = CLOSED.

13. (GCI_POSITION) This is a 3 element vector giving the spacecraft position (km) in GCI coordinates. This is copied from the orbit data file and is included here as a convenience.

14. (ATTITUDE) This is a 3 element vector giving the spacecraft attitude in GCI coordinates. This is calculated from the attitude data file and is included here as a convenience.

15. (GCI_SUN) This is a 3 element vector giving the sun position in GCI coordinates. This is taken from an ICSS_ call and is included here as a convenience.

16. (GCI_LOOK_DIR) This is a 3 element unit vector giving the look direction of the center of the UVI field of view in GCI coordinates.

17. (DSP_ANGLE; range: -180 to 180) This is the offset angle of the despun platform from the nadir angle in degrees, positive in the direction of spacecraft spin.

18. (FILTER; range: 2 to 6) The UVI KPGS may output one of 5 intensity images (one for each filter position). FILTER is an integer flag with the following values: 2 = OI 1304, 3 = OI 1356, 4 = LBH short, 5 = LBH long, 6 = solar spectrum. A value of 1 is reserved for the shutter position which is not placed in the key parameter output file.

19. (IMAGE_DATA) This is the requested image data. The image is background-subtracted and calibrated to radiance values (Rayleigh). The data is a rectangular two dimensional array (228 rows x 200 columns) of REAL*4 pixel values. Only a circular region of the rectangular array contains valid image data. The corners of the image (non-valid image data) are filled with a fixed fill value (CORNER_FILL =-127).

The image orientation is given in terms of the UVI image plane coordinate system: +Z parallel to the spacecraft spin axis, +X along the UVI viewing axis, and +Y to form a right-handed system (pointing in the outboard direction of the despun platform). The UVI image is in the YZ plane (illustrated below). Increasing row number corresponds to the -Z direction; increasing column number corresponds to the -Y direction.

20, 21. (GEODETIC_LAT; range: -90 to 90, GEODETIC_LONG; range: 0 to 360) For each pixel in IMAGE_DATA, pointing information is calculated in the form of geodetic latitude and longitude. These are written to two output images: latitude and longitude respectively. To save space, only a subset of the pixels is written to the UVI key parameter file. The pointing data images are sparse matrices representing every 10 pixels of IMAGE_DATA.

UVI Image Plane

(row,column)

(1,200)	⇒					(1,1)
⇓			↑			
			UVI +Z direction			
		← UVI +Y direction				
(228,1)						(228,1)

GEODETIC_* images

(IMAGE_DATA row, IMAGE_DATA column)

(5,195)	(5,185)	(5,175)		(5,5)
(15,195)	(15,185)	(15,175)		(15,5)
(25,195)	(25,185)	(25,175)	⇒	(25,5)
(35,195)	(35,185)	(35,175)		(35,5)
	⇓			
(225,195)	(225,185)	(225,175)		(225,5)

2.3 Processing Algorithm

The UVI KPGS processing algorithm is described below and in Figure 2.3.

1. Initial run setup (routine INIT_UVI_KPGS). All required files are opened and program variables are initialized. The UVI KPGS is run from a CDHF command file. All file operations such as opening/closing and read/write are controlled by CDHF support routines. Flags are also read from an input parameter file which determine the mode in which the UVI KPGS will be run. This is primarily for debugging purposes. For production runs, these flags will be fixed.

2. Read level-0 data and assemble image (FIND_SINGLE_IMAGE). The format of the level-0 data is given in Reference 2. For production data, four major frames are required to construct a single image frame. In addition to image data, UVI housekeeping data will be read and will be used for error checking and sequencing information for the viewing sequence.

3. Remove background. Part of each viewing sequence includes an image with the shutter closed, giving a measure of the fixed (instrumental) background. This is subtracted from the image data.

4. Correct image using calibration data and convert image data from digital words to radiance (kR) (CALIBRATE). An external calibration file is used to correct the image data for dependencies on operational parameters such as instrument gain and temperature. The calibration file provides a lookup table of calibration parameters for a given set of instrumental parameters. The calibration parameters are determined from preflight calibration of the instrument. Instrument response functions are used to convert from instrument count rates to units of radiance.

5. Calculate pointing information for the image (REGISTER_IMAGE).

6. Write results to output files (WRITE_KEY_PARMS). Calculated key parameters are written to the CDF key parameter file.

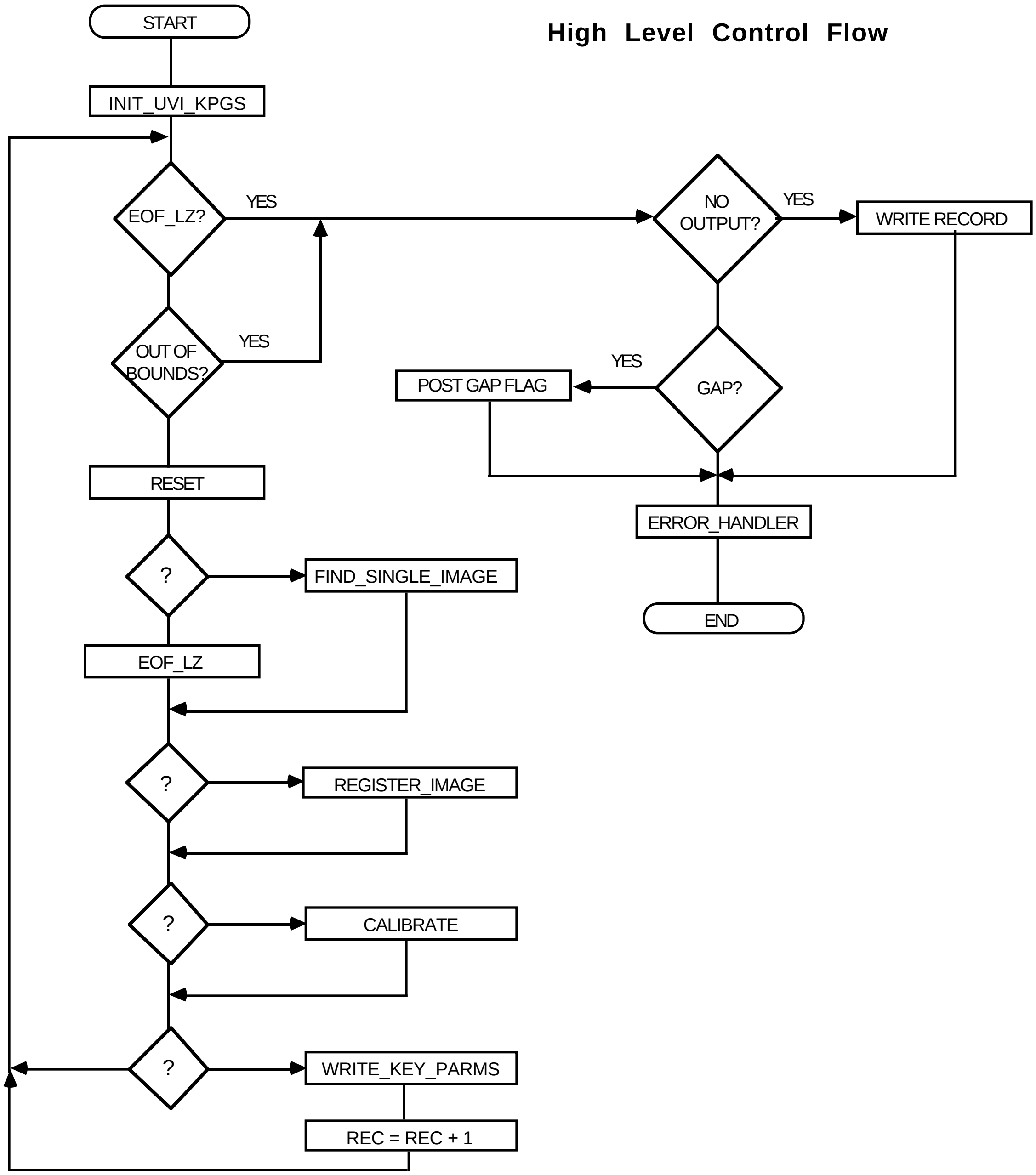

High Level Control Flow
START
INIT_UVI_KPGS
EOF_LZ?
YES
OUT OF BOUNDS?
YES
RESET
?
FIND_SINGLE_IMAGE
EOF_LZ
?
REGISTER_IMAGE
?
CALIBRATE
?
WRITE_KEY_PARMS
REC = REC + 1
NO OUTPUT?
YES
WRITE RECORD
YES
POST GAP FLAG
GAP?
ERROR_HANDLER
END

Figure 2.3

7. Go to step 2 and repeat until the end of the level-0 data is reached or a fatal error is encountered. Optionally, the user may specify a stop time beyond which the UVI KPGS stops processing. This is not a normal production mode and requires the setting of a switch hardcoded in the source code.

8. End algorithm. All open files are closed. Final messages are written to the user message file.

2.4 Software Architecture

The structure of the UVI KPGS is shown in Figure 2.4.

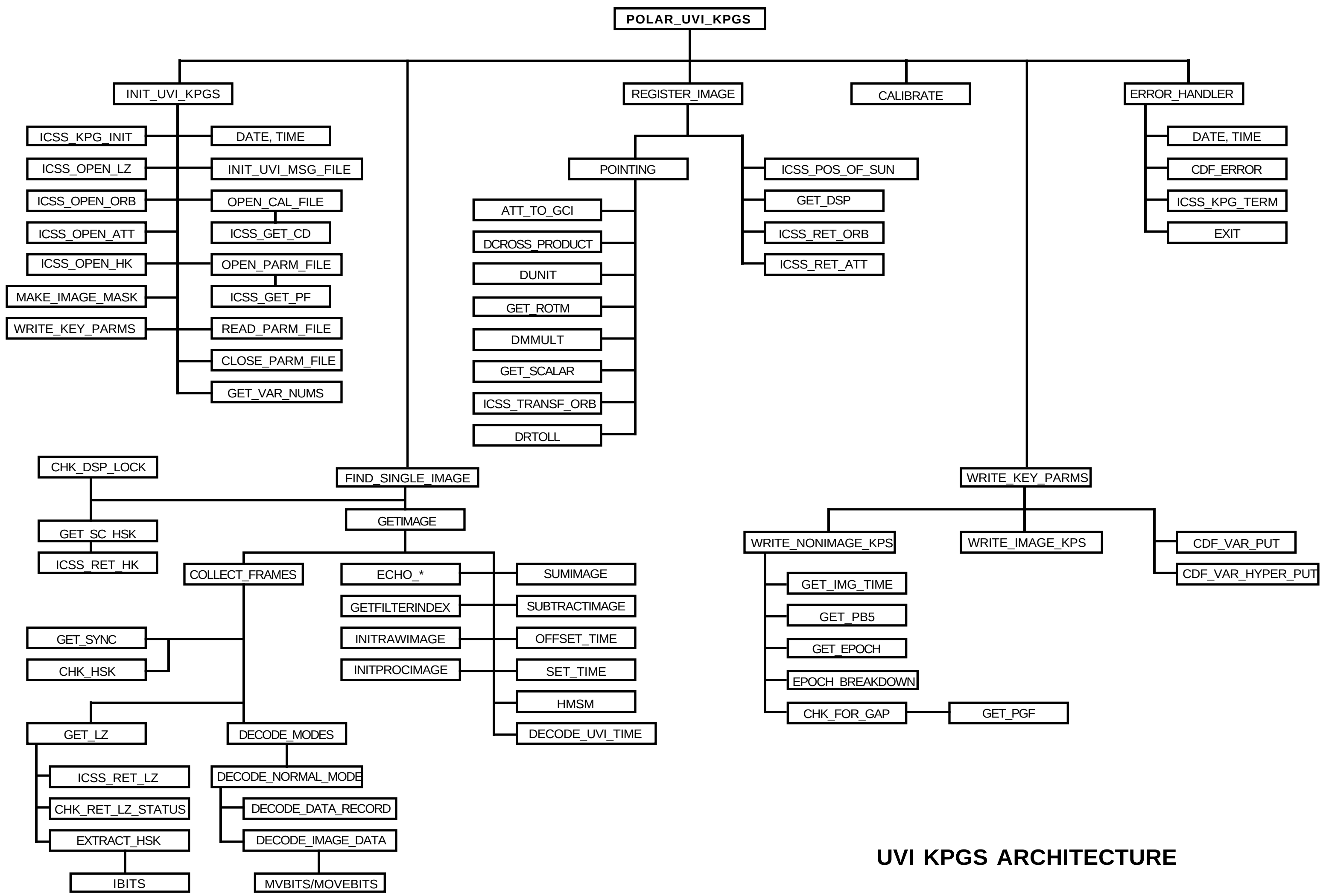
2.5 Error Handling

Standard ICSS error handling, as described in Reference 1, is performed by the UVI KPGS. In the event of ICSS fatal errors, a message is printed to the user message file and the KPGS terminates processing. In addition to the standard ICSS error handling the following special error handling is performed by the UVI KPGS.

1. Invalid/inappropriate data. In the event the UVI KPGS cannot decode the telemetry data, or the data is inappropriate because of viewing mode or other operational constraints, a message will be written to the user message file and the KPGS will continue looking for data to process.

2. Limit checking is performed on user input parameters. Out of range values are treated as fatal errors.

3. An initial message file is opened before the call to ICSS_KPG_INIT. This is copied to final user message file after the input parameter file is read.



UVI KPGS ARCHITECTURE

Figure 2.4

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3. PROGRAM GENERATION AND EXECUTION

3.1 Compilation and Linking Instructions

Compilation and linking of the UVI KPGS on the UVI CDHF are as follows. This is essentially the same procedure as given in Reference 1.

1. The source code is transferred to the CDHF development account as a VMS save set using a VMS copy command. The PACK.COM and UNPACK.COM command files are used to create the save set and to remove the elements from the save set, respectively.

2. The code is compiled and linked using the command files PO_UVI_COMPILE.COM and PO_UVI_RUN.COM, respectively.

3. The data file POUVI00001.DAT is modified to define input and output data files.

4. The data file PO_PF_*.DAT is modified to set the KPGS run modes.

5. The program is run using the command file PO_UVI_RUN.COM.

3.2 Sizing Considerations

The UVI KPGS source code occupies about 750 VMS blocks (384 kB). In the local development environment, a functional interface is provided for the ICSS_ calls. On the CDHF, the executable occupies about 5,780 VMS blocks (3 MB). On the CDHF the KPGS routines require about 2.5 MB. The Oracle database requires about 8.5 MB and additonal overhead increases the total virtual memory requirement to about 11.5 MB.

3.3 Timing Considerations

The UVI KPGS processed 24 hours of synthetic data on the CDHF in 27 minutes of cpu time and ran in 46 minutes (see Test 2 description below).

3.4 Program Test Instructions

The instructions for testing the UVI KPGS software in the ISTP CDHF environment are given below. UVI KPGS testing is in accordance with the guidelines outlined in Reference 3.

Two test cases are provided with the UVI KPGS referred to as Test 1 and Test 2, respectively.

3.4.1 Test 1

3.4.1.1 Description. This is a series of simulated failures designed to test the UVI KPGS error handling capabilities. The failures tested are: 1) non-9.2 second science telemetry mode, 2) non-normal instrument mode, 3) loss of first (of 4) major frame of image, 4) loss of image major frame other than first, 5) zero filled first minor frame of image, and 6) zero fill of minor frame other than first.

Since instrument configuration can determine how telemetry is decoded, these test are repeated for the following instrument & door position configurations: 1) primary system with door open, 2) secondary system with door open, 3) primary system with door closed, 4) secondary system with door closed.

The data set spans over 2 hours. This test illustrates the highest level of diagnostic output to the user message file.

3.4.1.2 Procedure. The test is executed by entering the following vms command:

```
$ @COM_DIR:PO_UVI_RUN_TEST1
```

This assumes the command $ KPGS_DEV has already been executed to define the test directory structure.

3.4.1.3 Data Input. The following files are required to execute Test 1.

```
TST_DIR:PO_UVI_INP_TEST1.DAT
TST_DIR:PO_PF_UVI_TEST1.DAT
POLAR_LZ:PO_LZ_UVI_19951101_V01.SFDU
POLAR_LZ:PO_LZ_SCR_19951101_V01.SFDU
POLAR_ORB:PO_OR_DEF_19951101_V01.SFDU
POLAR_ATT:PO_AT_DEF_19951101_V01.SFDU
```

3.4.1.4 Data Output. The following files are produced by Test 1.

```
TST_DIR:TEST1_START.ACC
TST_DIR:TEST1_STOP.ACC
```

TST_DIR:USR_MSG_FILE_TEST1.DAT
AT:[KPGS_DATA.UVI.TEST1]PO_K0_UVI_19951101_V01.CDF
AT:[KPGS_DATA.UVI.TEST1]PO_K0_UVI_19951101_V01.SFDU

3.4.1.5 Test Results. The UVI KPGS processed 804 frames of LZ telemetry covering over 2 hours, producing 15 output records with a nominal output period of five minutes. The routine properly handled all error conditions and terminated normally.

USR_MSG_FILE_TEST1.DAT is the KPGS log file. The *.ACC files contain accounting information.

The output cdf is 4868 VMS blocks (2.5 MBytes). The test required 3:01 (mm:ss) of cpu time and ran in about 4.5 minutes.

3.4.2 Test 2

3.4.2.1 Description. This test covers 24 hours of continuous LZ telemetry. The principal purpose of the test is to provide daily resource estimates for the UVI KPGS.

A secondary purpose is to test the behavior of the KPGS at the end of day boundary. This test illustrates the middle level of diagnostic output to the user message log.

3.4.2.2 Procedure. The test is executed by entering the following vms command:

$ @COM_DIR:PO_UVI_RUN_TEST2

This assumes the command $ KPGS_DEV has already been executed to define the test directory structure.

3.4.1.3 Data Input. The following files are required to execute Test 2.

TST_DIR:PO_UVI_INP_TEST2.DAT
TST_DIR:PO_PF_UVI_TEST2.DAT
POLAR_LZ:PO_LZ_SCR_19951003_V01.SFDU
POLAR_LZ:PO_LZ_UVI_19951003_V02.SFDU

POLAR_ORB:PO_OR_DEF_19951003_V01.SFDU
POLAR_ORB:PO_OR_DEF_19951003_V01.DAT
POLAR_ATT:PO_AT_DEF_19951003_V01.SFDU
POLAR_ATT:PO_AT_DEF_19951003_V01.DAT

3.4.2.4 Data Output. The following files are produced by Test 2.

TST_DIR:TEST2_START.ACC
TST_DIR:TEST2_STOP.ACC
TST_DIR:USR_MSG_FILE_TEST2.DAT
AT:[KPGS_DATA.UVI.TEST2]PO_K0_UVI_19951003_V02.DAT
AT:[KPGS_DATA.UVI.TEST2]PO_K0_UVI_19951003_V02.SFDU

3.4.1.5 Test Results. The input LZ file is 142 MBytes. 195 output records were produced for a nominal output period of 5 minutes. The output cdf is 71080 VMS blocks (36.4 MBytes). The user message file is 1532 VMS blocks (784 kBytes). The test required 28:00 (mm:ss) of cpu time and ran in 45 minutes.

The program ran without error or warning. The post gap and quality flags were nominal values (0 and 1248, respectively) for all records. The KPGS does reach the end of boundary. Rather it requests a record within a 2 minute gap at the end of the LZ file. This generates an INV_LZ_REQTIME error which is properly trapped, leading to proper program termination.